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MEMORANDUM REPORT No. 900

Air Blast Measurements Around Moving Explosive Charges, Part II (U)

BRADSHAW F. ARMENDT, JR.

DEPARTMENT OF THE ARMY PROJECT No. [illegible]
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. [illegible]

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 900

MAY 1955

AIR BLAST MEASUREMENTS AROUND MOVING EXPLOSIVE CHARGES, PART II (U)

Bradshaw F. Armendt, Jr.

Department of the Army Project No. 5B03-04-002
Ordnance Research and Development Project No. TB3-0112J

ABERDEEN PROVING GROUND, MARYLAND

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MEMORANDUM REPORT NO. 900

BFArmendt/plg
Aberdeen Proving Ground, Md.
May 1955

AIR BLAST MEASUREMENTS AROUND MOVING EXPLOSIVE CHARGES, PART II (U)

ABSTRACT

Additional blast measurements are taken around 1/8 pound, spherical explosive charges of Composition B, detonated while moving about 1750 feet per second, and compared to measurements obtained from similar charges detonated while at rest. The data obtained indicate that the side-on peak pressure and positive impulse are both increased in the direction of charge motion and decreased in the opposite direction. In the particular case shown, the peak pressure was increased by about 40% and the positive impulse was increased by about 30% in the forward direction.

A qualitative interpretation of the velocity effect, based partly on the data obtained, is suggested.

[redacted]

The work of Patterson and Wenig, as described in BRL Memorandum Report No. 767[1], was continued in an effort to collect more data regarding the effect of charge motion on the blast wave. The results of these additional experiments, together with a proposed explanation of the velocity effect are contained in this report.

With minor modifications, the experimental procedure of Patterson and Wenig was followed. A bare, spherical charge of Composition B,[2] weighing about 3/8 pound, was projected at a velocity of approximately 1750 feet per second and exploded in flight by means of magnetic induction. Blast gages placed around the point of detonation, at a distance of 2.71 feet, measured the side-on peak pressure and impulse of the shock wave. Stationary charges were fired also for the purpose of comparison.

Modifications of the original procedure include:

1. Use of side-on blast gages having 1/8-inch diameter piezoelectric crystals rather than the one-inch crystals employed previously. This results in much less distortion of the recorded pulse due to the finite size of the gage.

2. Direct calibration of the blast waveform gages by comparison with the peak pressures obtained from shock velocity measurements. This provides better estimates of the peak pressure and positive impulse from both moving and stationary explosive charges.

3. Removal of the experimental setup from clayey soil to a concrete strip, thereby providing a more stable mounting for the gages and speeding the work during periods of inclement weather.

4. Use of an improved reference system for locating the point of detonation of the moving charges, resulting in increased accuracy of this measurement.

Many other less important changes were made in the experimental setup, resulting in increased convenience, safety, and reliability.

Side-on blast pressures were detected by pencil-type tourmaline crystal gages. The gage output was amplified, displayed on an oscilloscope, and recorded by General Radio streak cameras using 35mm film moving about two inches per millisecond. All records were read on a type 13 Telereader. Peak pressures and positive impulses were calculated from these readings.

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1 BRL Memorandum Report No. 767, "Air Blast Measurements Around Moving Explosive Charges," (U) J. D. Patterson and J. Wenig, March 1954. Report classified Confidential.

2 Composition B = 60/40, RDX/TNT.

Each gage was calibrated by firing stationary 3/8 pound pentolite charges and comparing its peak output with the peak pressure inferred from shock velocity measurements. Gage size error was calculated by the method of Arons and Cole,[3] utilizing values for the initial slope of the shock wave as shown by Theilheimer.[4] The average correction for gage size error was about 8% for the stationary rounds and varied between 6% and 11% for the moving rounds, depending on the position of the gage. This correction was subtracted from the peak pressure inferred from velocity gage measurements, and the result was compared to the waveform gage output for the purpose of calibration. Thus the gage constant was obtained independent of size effect. When experimental records were obtained, the gage peak pressure was calculated first, then gage size correction was calculated and added to obtain the true peak pressure. This procedure was necessary since gage size error is a large and variable factor in the measurements.

The position of the burst of the moving charge was located by triangulation, using cameras equipped with one-microsecond electronic shutters.

A summary of the data is made in Table I, and the results of the individual firings are shown in Tables II and III. For the stationary charges, the average peak pressure was 67.3 pounds per square inch with a standard deviation of the individual of 7.5% and the average positive impulse was 8.1 pound-milliseconds per square inch with a standard deviation of the individual of 10%.

Since the moving charges did not detonate exactly at the reference point because of the variations in the time of initiation, average values of the peak pressure and positive impulse could not be calculated as simply as for the stationary rounds. The following method was used to estimate the peak pressure and positive impulse at a distance of 2.71 feet from the moving charge as a function of angular position from the line of fire. It was noticed that although the deviations in absolute distance from the intended burst were significant, the deviations in angular position were not. Therefore it was assumed that the nominal angles were obtained. Over the small interval of distance involved, the dependence of peak pressure and impulse on distance was assumed to be linear and linear least square fits were made to the observed values. The values of the peak pressure and positive impulse at the distance 2.71 feet and angles of 15°, 45°, and 105° from the line of fire were obtained from these fits. The tabulated values of Table I are plotted on polar graph paper in Figures I and II.

---

[3] Journal of the Acoustical Society of America, Vol. 22, No. 1, January 1950, A. B. Arons and R. H. Cole, "Design and Use of Piezoelectric Gages for the Measurement of Large Transient Pressures."

[4] NAVORD Report 1734, "The Determination of the Time Constant of a Blast Wave from the Pressure-Distance Relation," F. Theilheimer, December 1950.

Thornhill and Hetherington[5] predict that close to the surface of a moving charge, the shock velocity, and thus inference of the peak pressure, can be approximated by vectorial addition of the shock velocity for the stationary charge and the terminal velocity. However, at large distances from the charge, the terminal velocity increment to be added vectorially must approach zero, since the shock velocity approaches the velocity of sound. Thus the terminal velocity increment should decay in some manner between these two points, as illustrated in Figure III. For the particular case investigated (i.e., 2.71 feet from a charge moving about 1750 ft/sec) it would be expected that the increase in peak pressure in the forward direction could be inferred from a vectorial addition to the static shock velocity of a velocity increment somewhat smaller than 1750 ft/sec. Therefore, the peak pressures from Table I were used to infer the shock velocities by means of the Rankine-Hugoniot equation,[6] and the results plotted in Figure IV. It was observed that the values obtained for the moving rounds fall approximately on a circle of the same radius as for the static rounds, but with the center shifted about Mach 0.3 in the direction of motion, corresponding to a vectorial addition of [illegible] ft/sec to the shock velocity of the stationary rounds.

In order to be able to predict the peak pressure about a moving charge it is planned to obtain more data to investigate the possibility of establishing a decay curve of the type shown in Figure III.

The data for the positive impulse (Figure II) show an enhancement in the direction of motion of the charge, but no simple scheme for prediction of the enhancement has been suggested.

Bradshaw F. Armendt, Jr.

BRADSHAW F. ARMENDT, JR.

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5 ARE Memo 6153, "Some Notes on Explosions of Moving Charges," C. K. Thornhill and R. Hetherington, April 1952.

6 $$\frac{P_s}{P_o} = \frac{2\gamma}{\gamma - 1}\left[\frac{v^2}{c^2} - 1\right]$$

Where: P_s = peak excess pressure
P_o = ambient pressure
v = shock velocity
c = sound velocity
γ = ratio of specific heats for air

TABLE I

SUMMARY OF EXPERIMENTAL RESULTS

Charge Velocity	0 ft/sec	1753 ft/sec Angle from line of flight		
		15°	45°	105°
Peak Pressure (psi)	67.3	71.0	82.0	52.5
Positive Impulse (psi-ms)	8.1	10.2	9.8	7.9

TABLE II

EXPERIMENTAL DATA FROM STATIONARY CHARGES

Round Number	Angle from Line of Flight (degrees)	Distance from Charge (feet)	Charge Velocity (feet/sec)	Peak Pressure (lb/in²)	Positive Impulse (lb-ms/in²)
405	105	2.72	0.0	53.9	7.96
	45	2.72	0.0	64.7	7.44
412	105	2.72	0.0	62.2	6.56
	15	2.72	0.0	63.5	6.75
	45	2.72	0.0	71.1	7.40
414	105	2.72	0.0	73.0	8.80
	45	2.72	0.0	70.8	7.87
	15	2.72	0.0	63.8	7.90
	15	2.72	0.0	72.0	7.80
	45	2.72	0.0	67.3	7.93
426	15	2.72	0.0	64.9	4.78
429	105	2.72	0.0	72.2	8.85
	15	2.72	0.0	62.8	6.92
	45	2.72	0.0	64.7	8.25
441	15	2.72	0.0	66.2	8.32
	15	2.72	0.0	71.0	8.96

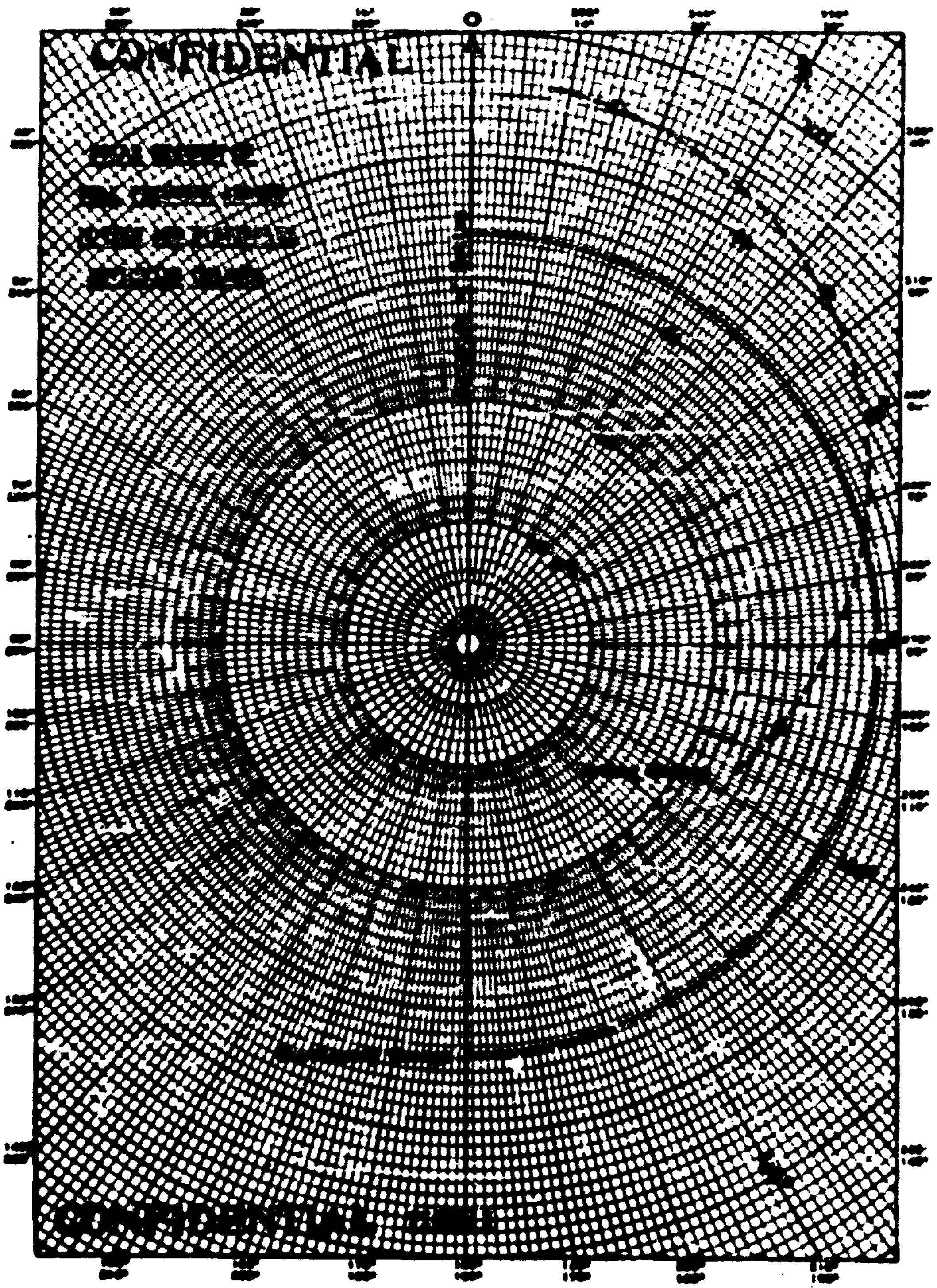
TABLE II (CONT)

Round Number	Angle from Line of Flight (degrees)	Distance from Charge (feet)	Charge Velocity (feet/sec)	Peak Pressure (lb/in^2)	Positive Impulse ($lb\text{-}ms/in^2$)
451	105	2.71	0.0	70.0	8.00
	45	2.71	0.0	77.6	7.11
455	105	2.71	0.0	75.2	9.66
	45	2.71	0.0	68.6	8.75
460	15	2.71	0.0	59.4	7.09
472	105	2.71	0.0	71.0	9.37
479	105	2.71	0.0	69.1	7.69
	45	2.71	0.0	70.4	9.88
	45	2.71	0.0	66.2	8.17
493	105	2.71	0.0	64.8	8.62
	15	2.71	0.0	66.3	8.67
	45	2.71	0.0	65.7	8.38
			Average	67.3	8.08
		Standard Deviation		7.9%	9.9%

TABLE III

EXPERIMENTAL DATA FROM MOVING CHARGES

Round Number	Angle from Line of Flight (degrees)	Distance from Charge (feet)	Charge Velocity (ft/sec)	Peak Pressure (lb/in^2)	Positive Impulse ($lb\text{-}ms/in^2$)
404	103.9	2.58	1713	61.2	8.27
	45.5	2.85	1713	73.5	5.91
411	100.6	2.85	1661	46.4	7.73
	18.4	2.60	1661	102.9	8.66
	44.9	2.45	1661	80.6	9.07
413	113.5	2.97	1677	41.5	7.30
	54.6	2.48	1677	102.4	9.67
	20.6	2.28	1677	95.9	11.08
	15.7	2.22	1677	99.1	8.33
	51.7	2.31	1677	77.7	8.49
425	12.1	2.96	1644	91.0	9.92
440	12.9	2.53	1802	91.4	11.51
	18.8	2.60	1802	103.2	9.96
450	107.9	2.79	1811	48.3	7.55
	46.8	2.57	1811	86.2	9.74
454	102.0	2.76	1872	53.7	8.29
	46.8	2.75	1872	77.7	11.24
459	14.8	2.70	1752	82.6	11.48
472	117.9	3.09	1750	35.4	6.27
478	111.9	2.83	1793	51.3	6.79
	50.8	2.48	1793	57.0	8.82
	50.8	2.47	1793	53.7	9.41
492	107.5	2.60	1808	50.1	—
	12.5	2.60	1808	77.6	—
	48.2	2.76	1808	80.9	—
		Average	1753		
		Standard Deviation	4.15		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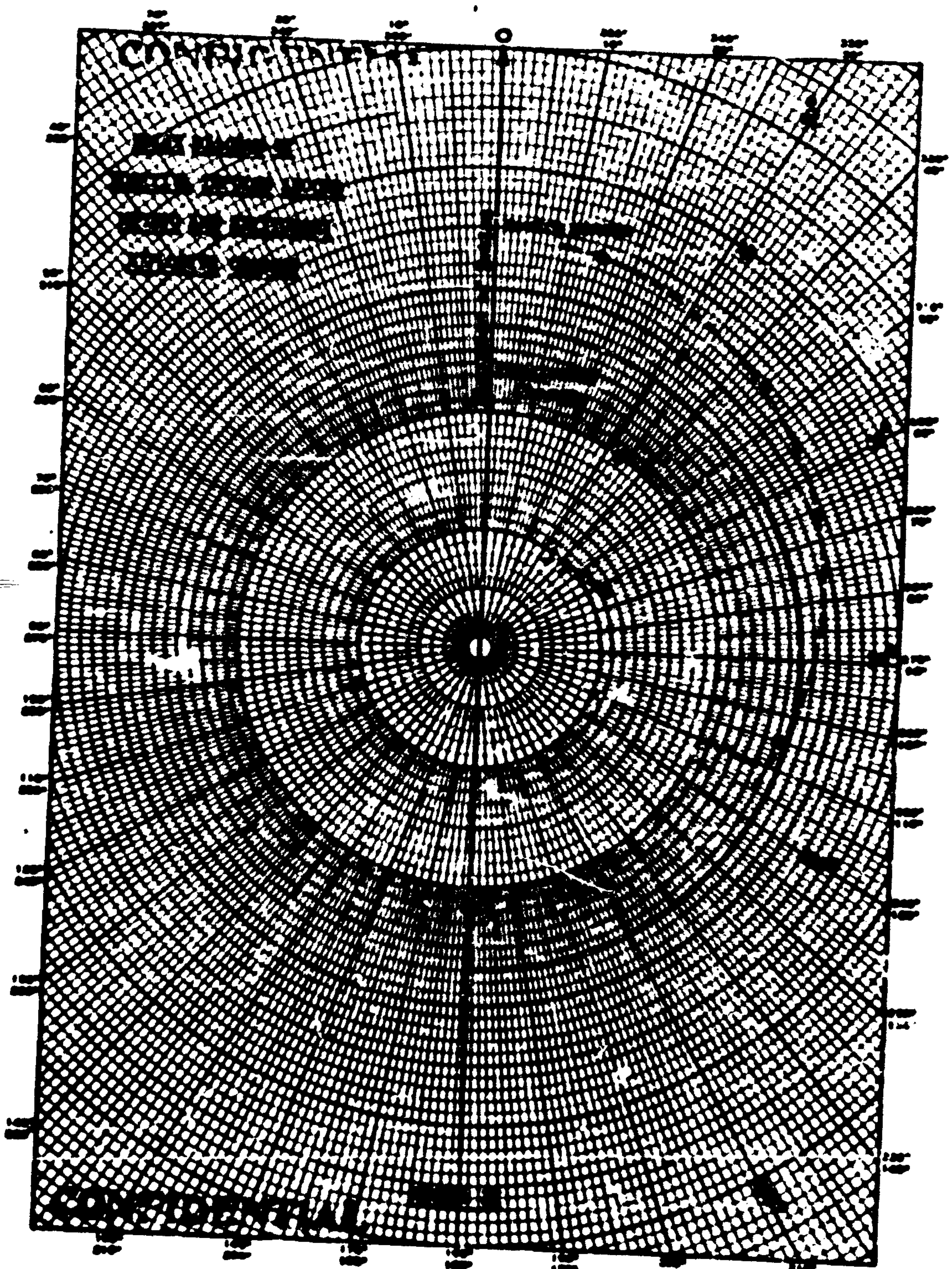

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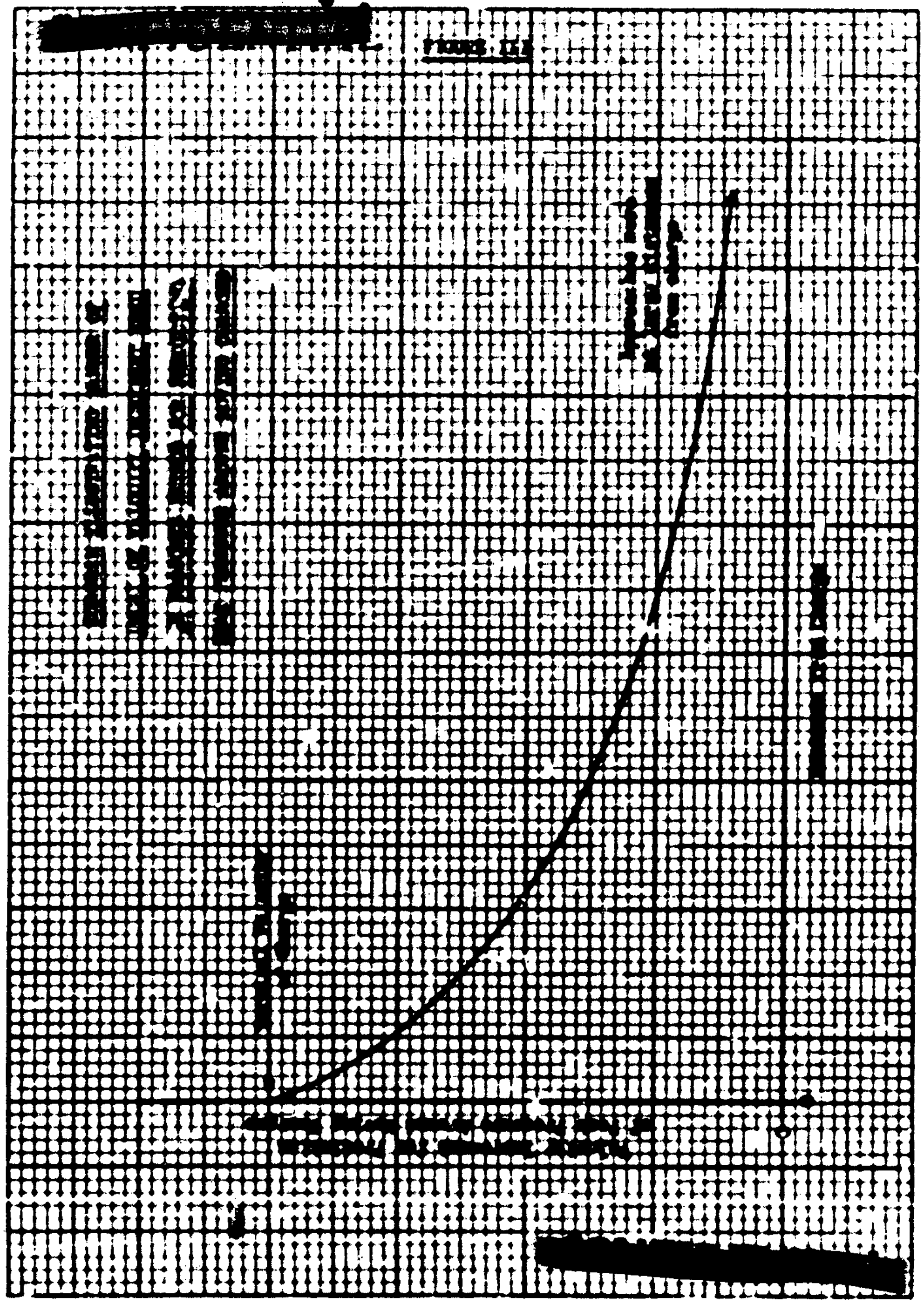

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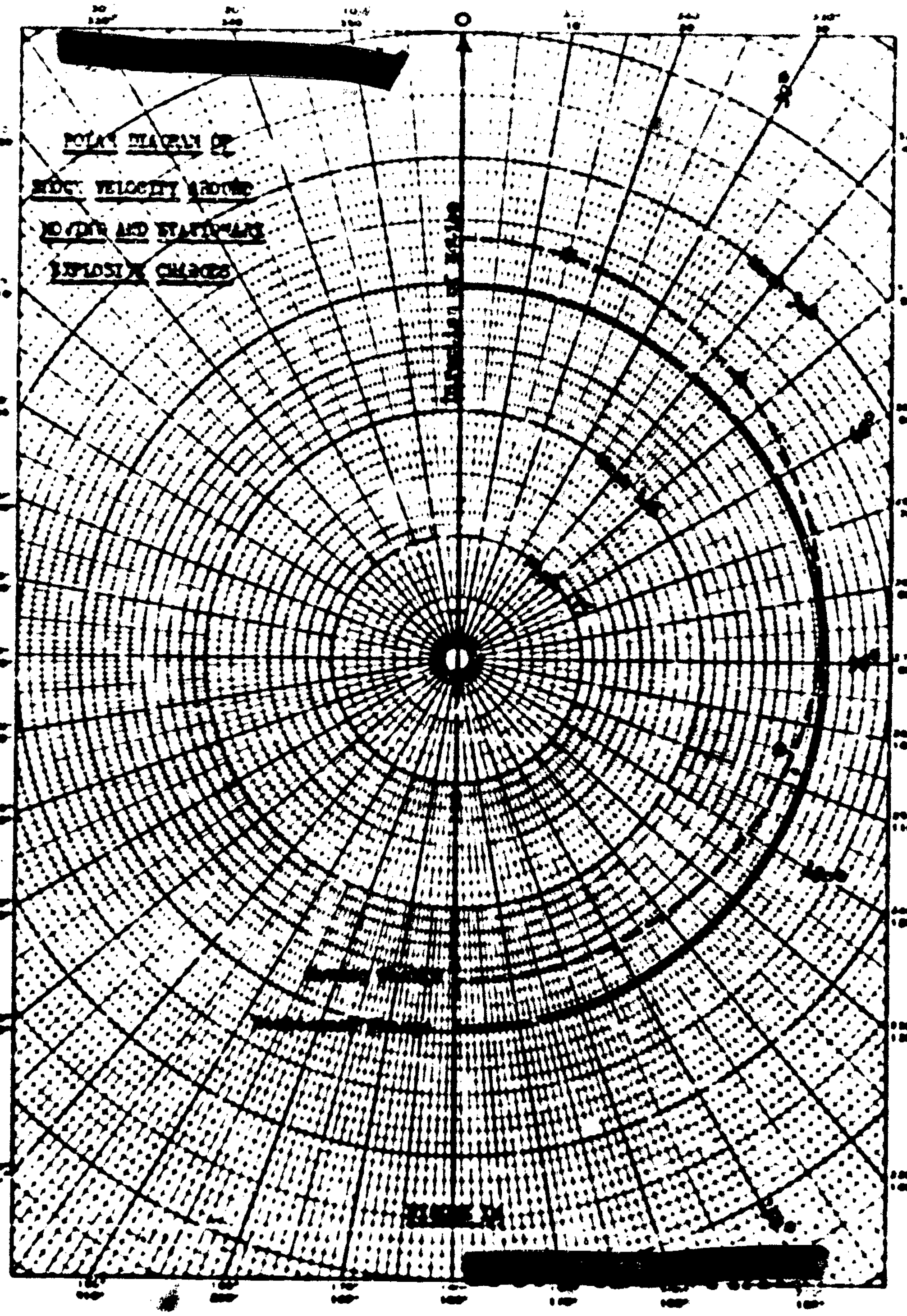

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